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Silicon Solar Cell Process
Development, Fabrication and Analysis

FIRST QUARTERLY REPORT

For Period Covering

August 28, 1978 to December 31, 1978

By

Joseph A. Minahan

JPL Contract No. 955055

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Spectrolab, Inc.
12500 Gladstone Avenue
Sylmar, California 91342

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"The JPL Low-Cost Silicon Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DOE."

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ABSTRACT

A program plan, baseline process, measurement program and qualtiy control plan have been generated as enunciated by the contract.

Cutting operations have been completed on the Wacker Silso silicon sheet material. The first fabrication run of Wacker Silso polycrystalline silicon into solar cells by the baseline process has been completed. Average conversion efficiency for solar cells fabricated by the baseline process from Wacker Silso sheet and measured at air mass zero was 10.4%, compared with the control cells, fabricated from single crystal CZ silicon, whose average conversion efficiency was 12.2%.

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I INTRODUCTION

Effort is being directed toward the evaluation of the solar cell potential of unconventional silicon sheets of interest to the Large Area Silicon Sheet (LASS) Task of the Low-Cost Solar Array (LSA) Project. The purpose of this program is to fabricate statistically significant numbers of solar cells using standard and reproducible processes and reliable testing of these cells using standardized measurement equipment and techniques. An additional purpose of this program is to investigate, develop and utilize technologies appropriate and necessary for improving the efficiency of solar cells made from silicon sheets using a standard process as the baseline starting point. Program goal for solar efficiency at Air Mass Zero (AMO) is 12%, measured at $28^{\circ}C$ minimum.

II TECHNICAL DISCUSSION

Cutting operations have been performed on the Wacker Silso sheet material. This material, 10 cm by 10 cm, must first be mounted on ceramic block and cut into four 5 cm by 5 cm sections. On the first sheet some breakage occurred during the mounting operation but was not a problem on the several that followed. Initial thickness of the sheet is approximately .04 cm and before reduction to cell size (2 cm by 2 cm) the material must be etched to a finished thickness of approximately .024 cm. The 5 cm by 5 cm sections are etched to the desired thickness by reaction in a hydrofluoric-nitric-acetic acid solution. After the etching operation the sections are cut into 2 cm by 2 cm wafers with an expected yield of 16 wafers per sheet.

A number of the Wacker sheets have been processed into the 2 cm by 2 cm wafers.

The first batch of Wacker Silso material has been fabricated into solar cells by the baseline process. The wafer group used for the 2 cm x 2 cm solar cells was made up of central portions of two sheets. Six Wacker wafers were processed along with eight control cells. Two of the Wacker cells were broken during the fabrication process, whereas none of the control wafers were damaged.

2.1 Results

Results of this run are given in the table. The cells, with Ta_2O_5 AR interference film, had an average efficiency at Air Mass Zero of 10.4%. This efficiency is based upon an irradiance of 135.3 mW/cm^2 and was calculated using the total device area. Average efficiency for the control cells was 12.2%.

2.2 Current-Voltage Measurement System

Current-voltage relations for the solar cells have been obtained using the Spectrolab X-25 Mark III Solar Simulator, as source. Short circuit current and open circuit voltage are measured by means of the Dana Model 5400 digital voltmeter in combination with a Spectrolab 380-31B Production Test Set. I-V curves are generated by means of an electronic load, Model D-550, and a Hewlett-Packard X-Y recorder. Test stand temperature is controlled by a recirculating water bath. Calibration of measurement is obtained using a balloon-flowr standard solar cell, #1037.

TABLE

Run W-4 $T=28^{o}C$

S/N	I_M,A	V_M,V	I_{sc},A	V_{oc},V	CFF	η,%	P_{max},m
1*	.132	.500	.142	.594	.78	12.0	66.2
2*	.133	.505	.142	.598	.79	12.5	67.3
5*	.130	.500	.139	.594	.79	12.0	65.0
6*	.132	.503	.142	.598	.78	12.3	66.6
9*	.133	.505	.141	.598	.80	12.5	67.3
10*	.133	.505	.143	.598	.78	12.4	67.0
13*	.129	.497	.142	.596	.76	11.8	63.9
14*	.131	.507	.141	.598	.79	12.3	66.4
Aver *	.132	.503	.142	.597	.78	12.2	66.2
S *	.002	.003	.001	.002	.01	.3	1.2
3	.124	.450	.133	.549	.76	10.3	55.8
4	.126	.455	.134	.554	.77	10.6	57.3
11	.124	.453	.133	.557	.76	10.4	56.2
12	.122	.459	.132	.557	.76	10.3	56.0
8	broken						
7	broken						
Aver	.124	.454	.133	.553	.76	10.4	56.3
S	.002	.004	.001	.004	.005	.14	.67
Range,Cont	.004	.006	.004	.004	.04	.7	3.4
Range,Poly	.004	.009	.002	.008	.01	.3	1.5

I_M = current at maximum power
V_M = voltage at maximum power
I_{sc}= short circuit current
V_{oc}= open circuit voltage
CFF= curve fill factor
η = conversion efficiency, percent
P_M = maximum power
S = sample standard deviation
* = control sample, single crystal

The X-25 Mark III Solar Simulator consists of a 2.5 KW Xenon short-arc lamp, an aconic collector, and lenticular transfer optics. The latter consists of nineteen individual lenses and filters, allowing very close matching to the solar spectrum and constant. Under the present operating conditions the Simulator produces a 15" diameter beam at the measurement plane with ± 2% uniformity.

III PROGRAM PROGRESS

The contract was late in starting owing to the manpower distribution. Although progress has been made in this regard it is expected that correction of this distribution problem will not be immediate. Some time will be required in the training of new personnel to familiarize them with methods involved in the contract.

IV SUMMARY AND RECOMMENDATIONS

The first lot of unconventional silicon material has been received from JPL. The material, Wacker Silso polycrystalline sheet, has been cut, etched to the required thickness, diced and made into solar cells by the baseline process. A minimum of breakage was observed during these operations. Some delay in the program has been noted and this has been attributed to manpower distribution.

Initial results on the Wacker material are surprising in view of the large number of grain boundaries to be found in this material. Because grain boundaries are regions of high defect density they must be expected to act as recombination centers, thereby reducing the effective minority carrier diffusion length of the material. Additional cells should be fabricated by the baseline process to determine the variation of quality across the whole sheet. After this has been accomplished, optimization of the process for this material should be undertaken.

V WORK PLANNED

More of the Wacker sheet material will be fabricated into solar cells by the baseline process. When this has been accomplished and the results analyzed recommendations will be made to JPL on methods that might be introduced into the processing to obtain optimized cells. After completion of the optimized Wacker cells work will commence on fabrication of solar cells by the baseline process using another of the unconventional silicon materials.